Federal Aviation Administration – Regulations and Policies
Aviation Rulemaking Advisory Committee

Transport Airplane and Engine Issue Area
Engine Harmonization Working Group

Task 11 – Safety and Failure Analysis

Task Assignment

[Federal Register: October 20, 1998 (Volume 63, Number 202)]
[Notices]
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DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

Aviation Rulemaking Advisory Committee; Transport Airplane and Engine Issues--New Tasks

AGENCY: Federal Aviation Administration (**FAA**), DOT.

ACTION: Notice of new task assignments for the Aviation Rulemaking Advisory Committee (ARAC).

SUMMARY: Notice is given of new tasks assigned to and accepted by the Aviation Rulemaking Advisory Committee (ARAC). This notice informs the public of the activities of ARAC.

FOR FURTHER INFORMATION CONTACT:
Stewart R. Miller, Transport Standards Staff (ANM-110), Federal Aviation Administration, 1601 Lind Avenue, SW., Renton, WA 98055-4056; phone (425) 227-1255; fax (425) 227-1320.

SUPPLEMENTARY INFORMATION:

Background

The **FAA** has established an Aviation Rulemaking Advisory Committee to provide advice and recommendations to the **FAA** Administrator, through the Associate Administrator for Regulation and Certification, on the full range of the **FAA**'s rulemaking activities with respect to aviation-related issues. This includes obtaining advice and recommendations on the **FAA**'s commitment to harmonize its Federal Aviation Regulations (FAR) and practices with its trading partners in Europe and Canada.

One area ARAC deals with is Transport Airplane and Engine Issues. These issues involve the airworthiness standards for transport category airplanes and engines in 14 CFR parts 25, 33, and 35 and parallel provisions in 14 CFR parts 121 and 135.

The Tasks

This notice is to inform the public that the **FAA** has asked ARAC to provide advice and recommendation on the following harmonization tasks:

Task 11: Safety and Failure Analysis

1. JAR-E requires a summary listing of all failures which result in major or hazardous effects and an estimate of the probability of

occurrence of these major and hazardous effects. Part 33 requires an assessment of failures which lead to four specified hazards.

2. JAR requires a list of assumptions and the substantiation of those assumptions. Most of the JAR-E assumptions are covered by other Part 33 paragraphs.

3. JAR-E includes a unique hazard, ``toxic bleed air''.

4. While both regulations require analysis to examine malfunctions and single and multiple failures. Part 33 also requires an examination of improper operation.

The **FAA** expects ARAC to submit its recommendation(s) resulting from this task by January 31, 2000.

Task 12: Endurance Test Requirements Study

Review and evaluate the feasibility and adequacy of harmonizing: (1) FAR 33.87 and JAR-E 740 endurance test requirements, including thrust reverser operation during endurance testing, in consideration of changes in engine technology; and (2) FAR 33.88 and JAR-E 700 overtemperature/excess operating conditions. The Aviation Rulemaking Advisory Committee (ARAC) is specifically tasked to study these issues and document findings in the form of a report.

The **FAA** expects ARAC to submit the report by December 31, 1999.

The report must include industry-provided data for an **FAA** economic analysis. This data should include the effects on small operators and small businesses. The report also should include industry-provided data regarding the record-keeping burden on the public.

Task 13: Fatigue Pressure Test/Analysis

JAR-E 640(b)(2) requires fatigue pressure testing of major engine casings. The FAR's do not have a specific requirement for fatigue pressure tests of major engine casings.

The **FAA** expects ARAC to submit its recommendation(s) resulting from this task by January 31, 1999.

Task 14: Overtorque

JAR-E 820 requires testing at maximum over-torque in combination with maximum turbine-entry and the most critical oil-inlet temperatures for the power turbine to validate transient overtorque values. The **FAA** does not have a specific requirement. Note: The 33.87 endurance test includes requirements that can be used to satisfy JAR-E requirements.

The **FAA** expects ARAC to submit its recommendation(s) resulting from this task by January 31, 1999.

Task 15: Compressor/Fan and Turbine Shafts

1. JAR-E 850 establishes probability limits for shaft failures based on the consequences of the failure. If the consequences of a shaft failure are not readily predictable, a test is required to determine the consequences. FAR 33.27(c)(2)(vi) requires all shaft failures, regardless of failure probability, to be considered when determining rotor integrity requirements.

2. ACJ E 850 provides guidance to determine the likelihood of a failure at a given location on a shaft and also provides guidance for

conducting tests to determine the dynamic characteristics and fatigue capability of the shaft. The FAR's do not provide any guidance material.

The **FAA** expects ARAC to submit its recommendation(s) resulting from this task by January 31, 2000.

Task 16: Electrical and Electronic Engine Control Systems

1. Advisory material exists for JAR-E (AMJ 20X-1). Advisory material does not exist for Part 33, which has caused difficulty during certification programs.

2. AMJ 20X-1 clearly defines the engine/airframe substantiation responsibilities, while FAR material does not define these requirements.

3. JAR-E states that an electronic control system ``should provide for the aircraft at least the equivalent safety, and the related reliability level, as achieved by Engines/Propellers equipped with hydromechanical control and protection systems.'' Part 33 does not state a desired reliability level. Part 33 states that failures must not result in unsafe conditions.

The **FAA** expects ARAC to submit its recommendation(s) resulting from this task by January 31, 2000.

For the above tasks the working group is to review airworthiness, safety, cost, and other relevant factors related to the specified difference, and reach consensus on harmonization of current Part 33/ JAR-E regulations and guidance material.

The **FAA** requests that ARAC draft appropriate regulatory documents with supporting economic and other required analyses, and any other related guidance material or collateral documents to support its recommendations. If the resulting recommendation(s) are one or more notices of proposed rulemaking (NPRM) published by the **FAA**, the **FAA** may ask ARAC to recommend disposition of any substantive comments the **FAA** receives.

Working Group Activity

The Engine Harmonization Working Group is expected to comply with the procedures adopted by ARAC. As part of the procedures, the working group is expected to:

1. Recommend a work plan for completion of the tasks, including the rationale supporting such a plan, for consideration at the meeting of ARAC to consider transport airplane and engine issues held following publication of this notice.

2. Give a detailed conceptual presentation of the proposed recommendations, prior to proceeding with the work stated in item 3 below.

3. Draft appropriate regulatory documents with supporting economic and other required analyses, and/or any other related guidance material or collateral documents the working group determines to be appropriate; or, if new or revised requirements or compliance methods are not recommended, a draft report stating the rationale for not making such recommendations. If the resulting recommendation is one or more notices of proposed rulemaking (NPRM) published by the **FAA**, the **FAA** may ask ARAC to recommend disposition of any substantive comments the **FAA** receives.

4. Provide a status report at each meeting of ARAC held to consider transport airplane and engine issues.

The Secretary of Transportation has determined that the formation and use of ARAC are necessary and in the public interest in connection with the performance of duties imposed on the **FAA** by law.

Meetings of ARAC will be open to the public. Meetings of the Engine Harmonization Working Group will not be open to the public, except to the extent that individuals with an interest and expertise are selected to participate. No public announcement of working group meetings will be made.

Issued in Washington, DC, on October 13, 1998.

Joseph A. Hawkins,
Executive Director, Aviation Rulemaking Advisory Committee.

[FR Doc. 98-28038 Filed 10-19-98; 8:45 am]
BILLING CODE 4910-13-M

Recommendation Letter

400 Main Street
East Hartford, Connecticut 06108

Pratt & Whitney
A United Technologies Company

From Bernice

April 4, 2000

Federal Aviation Administration
800 Independence Avenue, SW
Washington, D.C. 20591

#11

Attention: Mr. Anthony Fazio, ARM-1

Subject: Request for Formal Economic and Legal Review - ARAC Taskings

Dear Tony,

The Transport Airplane and Engine Issues group is pleased to submit the following documents to the FAA for formal economic and legal review.

- FAR 33.75 Engine Safety Analysis - NPRM and Advisory Circular
- FAR 33, One Engine Inoperative - NPRM and Advisory Circular

These documents have been prepared by the Engine Harmonization Working Group of TAEIG.

Sincerely yours,

Craig R. Bolt

Craig R. Bolt
Assistant Chair, TAEIG

Attachments

Copy: *Marc Bouthillier, FAA-NER
Judith Watson, FAA-NER
*Kris Carpenter, FAA-NWR
*Effie Upshaw, FAA Washington, DC
*Jerry McRoberts, Rolls Royce Allison

*letter only

CRB01_040400

Recommendation

[4910-13]

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 33

[Docket No. XXXXX; Notice No. XXXXXX]

RIN 2120-XXXX

AGENCY: Federal Aviation Administration, DOT.

ACTION: Notice of proposed rulemaking (NPRM).

SUMMARY: This notice proposes to amend the safety analysis type certification regulation for aircraft turbine engines. This proposal harmonizes the FAA's type certification standards on this issue with requirements of the Joint Aviation Authorities (JAA). The proposed changes, if adopted, would establish a uniform safety analysis regulation for aircraft turbine engines certified in the United States under Title 14 of the Code of Federal Regulations (14 CFR) part 33 and in the JAA countries under Joint Aviation Requirements-Engines (JAR-E), simplifying airworthiness approvals for import and export.

FOR FURTHER INFORMATION CONTACT: Ann Azevedo, Engine and Propeller Standards Staff, ANE-110, Engine and Propeller Directorate, Aircraft Certification Service, FAA, New England Region, 12 New England Executive Park, Burlington, Massachusetts 01803-5299; telephone (781) 238-7117;

fax (781) 238-7199.

SUPPLEMENTARY INFORMATION:

Background

Aviation Rulemaking Advisory Committee (ARAC) Project

The FAA is committed to undertaking and supporting the harmonization of part 33 with JAR-E. In August 1989, as a result of that commitment, the FAA Engine and Propeller Directorate participated in a meeting with the Joint Aviation Authorities (JAA), AIA, and AECMA. The purpose of the meeting was to establish a philosophy, guidelines, and a working relationship regarding the resolution of issues identified as needing to be harmonized, including some where new standards are needed. All parties agreed to work in a partnership to jointly address the harmonization effort task. This partnership was later expanded to include the airworthiness authority of Canada, Transport Canada.

This partnership identified the safety and failure analysis regulations as a Significant Regulatory Difference in need of harmonization.

This proposal has been selected as an ARAC project. The issues were assigned to the Engine Harmonization Working Group (EHWG) of the Transport Airplane and Engine Issues Group (TAEIG) on **YYYY YY, 199Y (---------).** On **XXXX XX, 199X,** the TAEIG recommended to the FAA that it proceed with the rulemaking and associated advisory material. This NPRM and associated advisory material reflect the ARAC recommendations.

The intent of the Safety Analysis regulation

The ultimate objective of the safety analysis regulation is to ensure that the collective risk from all engine failure conditions is acceptably low. The basis is the concept that an acceptable total engine design risk is achievable by managing the individual risks to acceptable levels. This concept emphasizes reducing the risk of a event proportionally with the severity of the hazard it represents.

Explanation of differences between the regulations

JAR-E 510 is titled "Failure analysis"; §33.75 is titled "Safety analysis." JAR-E 510 currently requires a summary listing of all failures which result in major or hazardous effects, along with an estimate of the probability of occurrence of these major and hazardous effects. Section 33.75 currently requires an assessment that any probable malfunction, failure, or improper operation will not lead to four specific hazards.

JAR-E 510 requires a list of assumptions contained within the failure analysis and the substantiation of those assumptions. Most of the JAR-E 510 assumptions are covered by other part 33 paragraphs.

JAR-E 510 references the specific hazard of toxic bleed air. This hazard is not mentioned in §33.75.

Both regulations require analysis to examine malfunctions and single and multiple failures; however, §33.75 also requires an examination of improper operation.

Outcome of harmonization effort

The harmonized regulation uses the framework of the current JAR-E 510, while including specific hazards as in the current §33.75.

Discussion of Proposed Changes

Under §33.5, a new paragraph (c) is added to reflect the new requirement for the safety analysis assumptions to be included in the engine's installation and operation manual.

Section 33.74 is revised to reflect the new ordering system of the revised §33.75, including the addition of new specific conditions to be evaluated.

Section 33.75 is entirely rewritten under the format of the current JAA equivalent rule to reflect the harmonization activity as described above.

Section 33.76 is revised to reference the specific engine conditions listed as hazardous effects within §33.75. (Note: §33.76 has not been issued at this time.)

The Proposed Amendment

In consideration of the foregoing, the Federal Aviation Administration proposes to amend part 33 of Chapter I, Title 14 of the Code of Federal Regulations as follows:

PART 33 — AIRWORTHINESS STANDARDS: AIRCRAFT ENGINES

1. In §33.5, add paragraph (c) to read as follows:

<u>§33.5 Instruction manual for installing and operating the engine.</u>

* * * * *

(c) <u>Safety analysis assumptions.</u> The assumptions of the safety analysis as described in §33.75(d) with respect to the reliability of safety devices, instrumentation, early warning devices, maintenance checks, and similar equipment or procedures that are outside the control of the engine manufacturer.

* * * * *

2. Revise §33.74 to read as follows:

§33.74 Continued rotation.

If any of the engine main rotating systems will continue to rotate after the engine is shutdown for any reason while in flight, and if means to prevent that continued rotation are not provided; then any continued rotation during the maximum period of flight, and in the flight conditions expected to occur with that engine inoperative, must not result in any condition described in §33.75(g)(2)(i) through (vi).

3. Revise §33.75 to read as follows:

§33.75 Safety analysis.

(a) (1) An analysis of the engine, including the control system, shall be carried out in order to assess the likely consequence of all failures that can reasonably be expected to occur. This analysis will take account of –

(i) Aircraft-level devices and procedures assumed to be associated with a typical installation. Such assumptions will be stated in the analysis.

(ii) Consequential secondary failures and latent failures.

(iii) Multiple failures referred to in paragraph (d) of this section or that result in the hazardous engine effects defined in paragraph (g)(2) of this section.

(2) A summary shall be made of those failures that could result in major engine effects or hazardous engine effects as defined in paragraph (g) of this section, together with an estimate of the probability of occurrence of those effects.

(3) It shall be shown that hazardous engine effects are not predicted to occur at a rate in excess of that defined as extremely remote (probability range of 10^{-7} to 10^{-9} per engine flight hour). The estimated probability for individual failures may be insufficiently precise to enable the total rate for hazardous engine effects to be assessed. For engine certification, it is acceptable to consider that the intent of this paragraph is achieved if the probability of a hazardous engine effect arising from an individual failure can be predicted to be not greater than 10^{-8} per engine flight hour. It will also be accepted that, in dealing with probabilities of this low order of magnitude, absolute proof is not possible and reliance must be placed on engineering judgment and previous experience combined with sound design and test philosophies.

(4) It shall be shown that major engine effects are not predicted to occur at a rate in excess of that defined as remote (probability range of 10^{-5} to 10^{-7} per engine flight hour).

(b) If significant doubt exists as to the effects of failures and likely combination of failures, any assumption may be required to be verified by test.

(c) It is recognized that the probability of primary failures of certain single elements (for example, disks) cannot be sensibly estimated in numerical terms. If the failure of such elements is likely to result in hazardous engine effects, reliance must be placed on meeting prescribed integrity requirements. These instances shall be stated in the safety analysis.

(d) If reliance is placed on a safety system, such as safety devices, instrumentation, early warning devices, maintenance checks, and similar equipment or procedures, to prevent a failure progressing to hazardous engine effects, the possibility of a safety system failure in combination with a basic engine failure shall be covered. If items of a safety system are outside the control of the engine manufacturer, the assumptions of the safety analysis with respect to the reliability of these parts shall be clearly stated in the analysis and identified in the installation instructions under §33.5.

(e) If the acceptability of the safety analysis is dependent on one or more of the following items, they shall be identified in the analysis and appropriately substantiated.

(1) Maintenance actions being carried out at stated intervals. This includes the verification of the serviceability of items which could fail in a latent manner. These maintenance intervals must be published in the appropriate manuals. Additionally, if errors in maintenance of the engine, including the control system, could lead to hazardous engine effects, the appropriate procedures shall be included in the relevant engine manuals.

(2) Verification of the satisfactory functioning of safety or other devices at pre-flight or other stated periods. The details of this satisfactory functioning must be published in the appropriate manual.

(3) The provisions of specific instrumentation not otherwise required.

(f) If applicable, the safety analysis shall also include, but is not limited to, investigation of:

(1) indicating equipment;

(2) manual and automatic controls;

(3) compressor bleed systems;

(4) refrigerant injection systems;

(5) gas temperature control systems;

(6) engine speed, power, or thrust governors and fuel control systems;

(7) engine overspeed, overtemp, or topping limiters;

(8) propeller control systems; and

(9) engine or propeller thrust reversal systems.

(g) Unless otherwise approved by the Administrator and stated in the safety analysis, for compliance with part 33, the following failure definitions apply to the engine:

(1) An engine failure in which the only consequence is partial or complete loss of thrust or power (and associated engine services) from the engine shall be regarded as a minor engine effect.

(2) The following effects shall be regarded as hazardous engine effects:

(i) Non-containment of high-energy debris,

(ii) Concentration of toxic products in the engine bleed air for the cabin sufficient to incapacitate crew or passengers,

(iii) Significant thrust in the opposite direction to that commanded by the pilot,

(iv) Uncontrolled fire,

(v) Failure of the engine mount system leading to inadvertent engine separation,

(vi) Release of the propeller by the engine, if applicable,

(vii) Complete inability to shut the engine down.

(3) An effect falling between those covered in (g)(1) and (2) shall be regarded as a major engine effect.

4. Section 33.76 is amended to revise paragraph (b)(3) to read as follows:

§33.76 Bird ingestion.

* * * * *

(b) * * *

(3) Ingestion of a single large bird tested under the conditions prescribed in this section must not result in any condition described in §33.75(g)(2).

* * * * *

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: **GUIDANCE MATERIAL FOR 14 CFR 33.75, SAFETY ANALYSIS.**

Date: 12/13/99
Initiated By: Ann Azevedo, ANE-110

AC No: DRAFT 33.75-1
Change:

1. **PURPOSE**. This advisory circular (AC) describes acceptable methods, but not the only methods, for demonstrating compliance with the requirements of Title 14 of the Code of Federal Regulations (14 CFR) §33. Like all AC material, this AC is not, in itself, mandatory and does not constitute a regulation. While these guidelines are not mandatory, they are derived from extensive Federal Aviation Administration (FAA) and industry experience in determining compliance with the pertinent regulations. This AC will be incorporated into AC 33-2, Aircraft Type Certification Handbook, at a later date.

2. **RELATED READING MATERIAL**.

a. AC 25.1309-1A, System Design Analysis, 6/21/88.

b. Draft Significant Airworthiness Information Bulletin (SAIB) to be issued by ANE on multi-engine maintenance.

c. Joint Airworthiness Authority (JAA) AMJ 25.1309, System Design and Analysis, xx/xx/xx.

d. Society of Automotive Engineers (SAE), Document No. ARP 4754, Certification Considerations for Highly-Integrated or Complex Aircraft Systems, issued November 1996.

e. SAE Document No. ARP 926A, Fault/Failure Analysis Procedure.

f. SAE Document No. ARP 4761, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment, issued December 1996.

g. Carter, A.D.S., Mechanical Reliability (2nd ed.). Macmillan, 1986.

h. Systematic Safety Assessment (CAA Leaflet AD/IL/0092/1-7).

3. **APPLICABILITY**. This document is applicable to all turbine aircraft engines regulated by part 33.

4. **DEFINITIONS**. For the purposes of this AC, the following definitions are provided.

a. Analysis. A specific and detailed qualitative and/or quantitative evaluation of the engine offered for certification to determine compliance with §33.75. Examples include: Fault Tree Analysis (FTA), Failure Mode and Effects Analysis (FMEA) and Markov Analysis.

b. Assessment. A more general or broad evaluation of the engine which may include the results of the analysis completed, as well as any other information, to support compliance with §33.75.

c. Check. An examination, inspection and/or test to determine the physical integrity and/or the functional capability of an item.

d. Error. An omission or incorrect action by a crew member or people in charge of the maintenance or a mistake in requirements, design or implementation. An error may result in a failure but is not a failure in and of itself.

e. External Event. An occurrence originating apart from the engine or aircraft, including but not limited to icing or bird strikes.

f. Failure Condition. A condition with a direct, consequential engine-level effect, caused or contributed to by one or more failures. Examples include limitation of thrust to idle or oil exhaustion.

g. Failure Mode. The cause of the failure or the manner in which an item or function can fail. Examples include failures due to corrosion or fatigue, or failure in jammed open position.

h. Redundancy. Multiple independent methods incorporated to accomplish a given function, each one of which is sufficient to accomplish the function.

i. System. A combination of inter-related items arranged to perform a specific function(s).

j. Toxic Products. Products that act as or have the effect of a poison when humans are exposed to them.

5. BACKGROUND.

a. The ultimate objective of a safety analysis is to ensure that the risk to the aircraft from all engine failure conditions is within an acceptable range. The basis is the concept that an acceptable total engine design risk is achievable by managing the individual major and hazardous engine risks to acceptable levels. This concept emphasizes reducing the likelihood or probability of an event proportionally with the severity of its effects. The safety analysis should support the engine design goals such that there would not be major or hazardous engine effects occurring that exceed the required probability of occurrence as a result of engine failure modes.

b. Compliance with §33.75 should be shown by a safety analysis substantiated, when necessary, by appropriate testing and/or comparable service experience. An assessment may range from a simple report that offers descriptive details associated with a failure condition, an interpretation of test results, a comparison of two similar components or assemblies, other qualitative information, to a detailed safety analysis.

c. The depth and scope of an acceptable safety assessment depend on the complexity and criticality of the functions performed by the system(s), components or assemblies under consideration; the severity of related failure conditions; the uniqueness of the design and extent of relevant service experience; the number and complexity of the identified failures; and the detectability of contributing failures.

6. SECTION 33.75 - GENERAL.

a. Section 33.75 defines the engine-level failure conditions and presumed severity levels. Aircraft-level failure classifications are not directly applicable to engine safety assessments since the aircraft may have features that could reduce or increase the consequences of an engine failure condition. Additionally, the same type-certificated engine may be used in a variety of installations, each with different aircraft-level failure classifications.

b. Since aircraft-level requirements for individual failure conditions may be more severe than the engine-level requirements, due to installation effects, there should be early coordination between the engine manufacturer and the aircraft manufacturer, as well as the relevant FAA certification offices, to ensure that the engine may be installed in the aircraft. It is the aim of the FAA to help ensure the engine applicant is aware of possibly more restrictive regulations in the installed condition.

7. SECTION 33.75(a)(1).

a. Rule Text. The regulation in §33.75(a)(1) reads as follows: **"An analysis of the engine, including the control system, shall be carried out in order to assess the likely consequence of all failures that can reasonably be expected to occur. This analysis will take account of –**

(i) Aircraft-level devices and procedures assumed to be associated with a typical installation. Such assumptions will be stated in the analysis.

(ii) Consequential secondary failures and latent failures.

(iii) Multiple failures referred to in paragraph (d) of this section or that result in the hazardous engine effects defined in paragraph (g)(2) of this section."

b. Guidance.

(1) The reference to "typical installation" in paragraph 33.75(a)(1)(i) does not imply that the aircraft-level effects are known, but that assumptions of typical aircraft devices and procedures, such as fire-extinguishing equipment, annunciation devices, etc., are clearly stated in the analysis. Such assumptions should be included in the installation instructions under paragraph 33.5(c). Regulations within the aircraft paragraphs of 14CFR (Parts 23, 25, 27, and 29) contain aircraft-level device requirements. These regulations include xx.1305, Powerplant instruments.

(2) In showing compliance with §33.75(a)(1), a component level safety analysis may be an auditable part of the design process or may be conducted specifically for demonstration of compliance with this rule.

(3) The possible latency period of failures is included in the probabilistic calculations of failure rates.

8. **SECTIONS 33.75(a)(2) and 33.75(a)(3).**

a. Rule Text for §33.75(a)(2). The regulation in §33.75(a)(2) reads as follows: **"A summary shall be made of those failures that could result in major engine effects or**

hazardous engine effects as defined in paragraph (g) of this section, together with an estimate of the probability of occurrence of those effects."

b. Rule Text for §33.75(a)(3). The regulation in §33.75(a)(3) reads as follows: **"It shall be shown that hazardous engine effects are not predicted to occur at a rate in excess of that defined as extremely remote (probability range of 10^{-7} to 10^{-9} per engine flight hour). The estimated probability for individual failures may be insufficiently precise to enable the total rate for hazardous engine effects to be assessed. For engine certification, it is acceptable to consider that the intent of this paragraph is achieved if the probability of a hazardous engine effect arising from an individual failure can be predicted to be not greater than 10^{-8} per engine flight hour. It will also be accepted that, in dealing with probabilities of this low order of magnitude, absolute proof is not possible and reliance must be placed on engineering judgment and previous experience combined with sound design and test philosophies."**

c. Guidance.

(1) The occurrence rate of hazardous engine effects applies to each individual effect. The 10^{-7} to 10^{-9} range of probabilities for each hazardous engine effect applies to the summation of the probabilities of this hazardous engine effect arising from individual failure modes or combinations of failure modes other than the failure of critical components (i.e., disks, hubs, spacers). For example, the total rate of occurrence of uncontrolled fires, obtained by adding up the individual failure modes and combination of

failure modes leading to an uncontrolled fire, should not exceed 10^{-7}.

(2) When considering primary failures of certain single elements such as critical components, the numerical failure rate cannot be sensibly estimated. If the failure of such elements is likely to result in hazardous engine effects, reliance must be placed on their meeting the prescribed integrity requirements, such as §§33.14, 33.15 and 33.27, among others. These requirements are considered to support a design goal that, among other goals, primary LCF failure of the component should be extremely improbable (remote?) throughout its operational life. There is no requirement to include the estimated primary failure rates of such single elements in the summation of failures for each hazardous engine effect due to the difficulty in producing and substantiating such an estimate.

9. **SECTION 33.75(a)(4).**

a. Rule Text. The regulation in §33.75(a)(4) reads as follows: "**It shall be shown that major engine effects are not predicted to occur at a rate in excess of that defined as remote (probability range of 10^{-5} to 10^{-7} per engine flight hour).**"

b. Guidance. Compliance with (a)(4) can be shown if the individual failures or combinations of failures resulting in major engine effects have probabilities in the range of 10^{-5} to 10^{-7}. No summation of probabilities of failure modes resulting in the same major engine effect is required to show compliance with this rule.

10. **SECTION 33.75(b).**

a. Rule Text. The regulation in §33.75(b) reads as follows: **"If significant doubt exists as to the effects of failures and likely combination of failures, any assumption may be required to be verified by test."**

b. Guidance. Prediction of the likely progression of some engine failures may rely extensively upon engineering judgment and is not susceptible to absolute proof. If there is some question of the validity of such engineering judgment, to the extent that the conclusions of the analysis could be invalid, additional substantiation may be required. Additional substantiation may consist of reference to previous relevant service experience, engineering analysis, material, component, rig or engine test or a combination of the above. If significant doubt exists over the validity of the substantiation so provided, additional testing or other validation may be required.

11. **SECTION 33.75(c)**.

a. Rule Text. The regulation in §33.75(c) reads as follows: **"It is recognized that the probability of primary failures of certain single elements (for example, disks) cannot be sensibly estimated in numerical terms. If the failure of such elements is likely to result in hazardous engine effects, reliance must be placed on meeting prescribed integrity requirements. These instances shall be stated in the safety analysis."**

b. Guidance. The intent of this section is self-evident.

12. SECTION 33.75(d).

a. Rule Text. The regulation in §33.75(d) reads as follows: **"If reliance is placed on a safety system, such as safety devices, instrumentation, early warning devices, maintenance checks, and similar equipment or procedures, to prevent a failure progressing to hazardous engine effects, the possibility of a safety system failure in combination with a basic engine failure shall be covered. If items of a safety system are outside the control of the engine manufacturer, the assumptions of the safety analysis with respect to the reliability of these parts shall be clearly stated in the analysis and identified in the installation instructions under §33.5."**

b. Guidance. The safety system failure may be present as a latent failure, occur simultaneously with the basic engine failure, or occur subsequent to the engine failure.

13. SECTIONS 33.75(e) and 33.75(e)(1).

a. Rule Text for §33.75(e). The regulation in §33.75(e) reads as follows: **"If the acceptability of the safety analysis is dependent on one or more of the following items, they shall be identified in the analysis and appropriately substantiated."**

b. Rule Text for §33.75(e)(1). The regulation in §33.75(e)(1) reads as follows: **"Maintenance actions being carried out at stated intervals. This includes the verification of the serviceability of items which could fail in a latent manner. These maintenance intervals must be published in the appropriate manuals. Additionally, if errors in maintenance of the engine, including the control system, could lead to**

hazardous engine effects, the appropriate procedures shall be included in the relevant engine manuals."

c. Guidance.

(1) There should be general statements in the analysis summary that refer to regular maintenance in a shop as well as on the line. If specific failure rates rely on special or unique maintenance checks, those should be explicitly stated in the analysis.

(2) The engine maintenance manual, overhaul manual, or other relevant manuals may serve as the appropriate substantiation for (e)(1) above. A listing of all possible incorrect maintenance actions is not required.

d. Maintenance error lessons learned. Maintenance errors have contributed to hazardous or catastrophic effects at the aircraft level. Many of these events have arisen due to similar maintenance actions being performed on multiple engines during the same maintenance availability by one maintenance crew, and are thus primarily an aircraft-level concern. If appropriate, consideration should be given to communicating strategies against performing contemporaneous maintenance of multiple engines (see Significant Airworthiness Information Bulletin (SAIB) on multi-engine maintenance [ANE to release], ETOPS requirements, etc.) Consideration should be given to mitigating the effects of maintenance errors in the design phase. Components undergoing frequent maintenance should be designed to facilitate the maintenance and correct re-assembly. However, completely eliminating sources of maintenance error during design is not possible.

(1) The following list of multiple engine maintenance errors was constructed from situations that have repeatedly occurred in service and have caused one or more serious events:

(a) Failure to restore oil system or borescope access integrity after routine maintenance (oil chip detector or filter check). Similar consideration should be given to other systems.

(b) Mis-installation of O-rings.

(c) Servicing with incorrect fluids.

(2) Improper maintenance on parts such as disks, hubs, and spacers has led to failures resulting in hazardous effects. Examples of this which have occurred in service are overlooking existing cracks or damage during inspection and failure to apply or incorrect application of protective coatings (e.g., anti-gallant, anti-corrosive).

14. **SECTION 33.75(e)(2)**.

a. Rule Text. The regulation in §33.75(e)(2) reads as follows: **"Verification of the satisfactory functioning of safety or other devices at pre-flight or other stated periods. The details of this satisfactory functioning must be published in the appropriate manual."**

b. Guidance. If specific failure rates rely on special or unique maintenance checks for protective devices, those should be explicitly stated in the analysis.

15. **SECTION 33.75(e)(3)**.

a. Rule Text. The regulation in §33.75(e)(3) reads as follows: **"The provisions of specific instrumentation not otherwise required."**

b. Guidance. The intent of this section is self-evident.

16. **SECTION 33.75(f)**.

a. Rule Text. The regulation in §33.75(f) reads as follows: **"If applicable, the safety analysis shall also include, but is not limited to, investigation of:**

(1) indicating equipment;

(2) manual and automatic controls;

(3) compressor bleed systems;

(4) refrigerant injection systems;

(5) gas temperature control systems;

(6) engine speed, power, or thrust governors and fuel control systems;

(7) engine overspeed, overtemp, or topping limiters;

(8) propeller control systems; and

(9) engine or propeller thrust reversal systems."

b. Guidance. The safety analysis is not limited to the items listed in §33.75(f).

17. **SECTION 33.75(g)(1)**.

a. Rule Text. The regulation in §33.75(g)(1) reads as follows: **"Unless otherwise approved by the Administrator and stated in the safety analysis, for compliance with part 33, the following failure definitions apply to the engine:**

(1) An engine failure in which the only consequence is partial or complete loss of thrust or power (and associated engine services) from the engine shall be regarded as a minor engine effect."

b. Guidance.

(1) It is generally recognized that engine failures involving complete loss of thrust or power from the affected engine can be expected to occur in service, and that, for the purposes of the engine safety analysis, the aircraft is assumed to be capable of controlled flight following such an event. Therefore, for the purpose of the engine safety analysis and engine certification, engine failure with no effect other than loss of thrust and services may be regarded as a comparatively safe failure with a minor engine effect. This assumption may be revisited during aircraft certification, where installation effects such as engine redundancy may be fully taken into consideration. This reexamination applies only to aircraft certification and is not intended to impact engine certification.

(2) The failure to achieve any given power or thrust rating for which the engine is certificated should be both covered in the safety analysis and regarded as a minor engine effect. This assumption may be revisited during aircraft certification, particularly multi-engine rotorcraft certification. This reexamination applies only to aircraft certification and is not intended to impact engine certification.

18. **SECTION 33.75(g)(2).**

a. Rule Text for §33.75(g)(2)(i). The regulation in §33.75(g)(2)(i) reads as follows:

"The following effects shall be regarded as hazardous engine effects:

(i) Non-containment of high-energy debris,"

b. Guidance for §33.75(g)(2)(i).

(1) Uncontained debris covers a large spectrum of energy levels due to the various sizes and velocities of parts released by the engine. The engine has a containment structure which is designed to contain the release of a single blade and its consequences, and which is often adequate to contain additional released blades and static parts. The engine containment structure is not expected to contain major rotating parts should they fracture. Disks, hubs, impellers, large rotating seals, and other similar large rotating components should therefore always be considered to represent potential high-energy debris. Generally, multiple blades released, if uncontained, have used up most of their energy defeating the containment structure, and may typically be considered as low-energy debris.

(2) Fan blades may have significant residual energy after defeating the containment structure, depending on the specifics of engine size, bypass ratio, and other design elements. The choice of whether to include fan blade uncontainment under high energy (and thus, hazardous engine effects) or low energy (major engine effects) should be carefully considered.

(3) The engine casings generally provide the engine containment structure, as well as being pressure vessels. Thus, casing rupture due to pressure loads is inherently not contained by the normal blade containment provisions. Service experience has shown that the rupture of the highest pressure casings (compressor delivery pressure) can generate high-energy debris.

c. Rule Text for §33.75(g)(2)(ii). The regulation in §33.75(g)(2)(ii) reads as follows: **"Concentration of toxic products in the engine bleed air for the cabin sufficient to incapacitate crew or passengers,"**

d. Guidance for §33.75(g)(2)(ii).

(1) This effect may be interpreted as the generation and delivery of sufficient toxic products as a result of abnormal engine operation that could incapacitate the crew or passengers during the subject flight. This means that the flow of toxic products would either be so quick-acting as to be impossible to stop prior to incapacitation, and/or that there would be no effective means to stop the flow of toxic products to the crew compartment or passenger cabin, and/or that the toxic products would be undetectable prior to incapacitation. The toxic products could result, for example, from the degradation of abradable materials in the compressor when rubbed by rotating blades or the degradation of oil which would leak into the compressor air flow.

(2) No assumptions of cabin air dilution or mixing should be made in this engine-level analysis; those items can only be properly evaluated during aircraft certification. The intent of paragraph §33.75(g)(2)(ii) is to address the relative concentration of toxic

products in the engine bleed air delivery. The hazardous engine effect of toxic products relates to significant concentrations of toxic products, with "significant" defined as concentrations sufficient to incapacitate persons exposed to those concentrations.

(3) Since these concentrations are of interest to the installer, information on delivery rates and concentrations of toxic products in the engine bleed air for the cabin should be provided to the installer as part of the installation instructions.

e. Rule Text for §33.75(g)(2)(iii). The regulation in §33.75(g)(2)(iii) reads as follows:

"Significant thrust in the opposite direction to that commanded by the pilot,"

f. Guidance for §33.75(g)(2)(iii). Engine failures resulting in significant thrust in the opposite direction to that commanded by the pilot can, depending on the flight phase, result in a hazardous condition relating to aircraft controllability. Those failures, if applicable to part 33 certification, that could be classified as hazardous engine events include:

(1) Uncommanded thrust reverser deployment;

(2) Reverse propeller pitch in flight; or

(3) High forward thrust when reverse thrust is commanded.

g. Rule Text for §33.75(g)(2)(iv). The regulation in §33.75(g)(2)(iv) reads as follows:

"Uncontrolled fire,"

h. Guidance for §33.75(g)(2)(iv). An uncontrolled fire should be interpreted in this context as an extensive or persistent fire which is not effectively confined to a designated fire zone. Provision for flammable fluid drainage, fire containment, fire detection, and fire extinguishing may be taken into account when assessing the severity of the effects of a fire.

i. Rule Text for §33.75(g)(2)(v) and (vi). The regulation in §33.75(g)(2)(v) and (vi) reads as follows:

(v) "Failure of the engine mount system leading to inadvertent engine separation,"

(vi) "Release of the propeller by the engine, if applicable,"

j. Guidance for §33.75(g)(2)(v) and (vi). The intent of these paragraphs is self-evident.

k. Rule Text for §33.75(g)(2)(vii). The regulation in §33.75(g)(2)(vii) reads as follows: **"Complete inability to shut the engine down."**

l. Guidance for §33.75(g)(2)(vii).

(1) Complete inability to shut down the engine is regarded as a hazardous engine effect due to the potential circumstances in which continued running of the engine, even at low thrust or power, represents a hazard. These circumstances include the inhibition of safe evacuation of passengers and crew, directional control problems during landing due to the inability to eliminate thrust or power, or the inability to ensure safe shut down when required following a failure.

(2) It is acceptable to take allowance for aircraft-supplied equipment (fuel cutoff means, etc.) to protect against the "complete inability" to shut down the engine. Furthermore, the inclusion of "complete inability to shut the engine down" as a hazardous

engine effect is not intended to preclude hardware or software intended to protect against inadvertent engine shutdown, including aircraft logic to mitigate against the inadvertent shutdown of all engines.

19. SECTION 33.75(g)(3).

a. Rule Text. The regulation in §33.75(g)(3) reads as follows: **"An effect falling between those covered in (g)(1) and (2) shall be regarded as a major engine effect."**

b. Guidance. The following list is a guide to the scope of major engine effects. Major engine effects are likely to significantly increase crew workload, or reduce the safety margins between the engine operating condition and a hazardous engine failure. These items may not be applicable to all engines and the list is not intended to be exhaustive. Furthermore, engine design variations may result in changes to the classification of these failure conditions.

(1) Controlled fires (i.e., those brought under control by shutting down the engine or by on-board extinguishing systems).

(2) Case burnthrough where it can be shown that there is no propagation to hazardous engine effects.

(3) Release of low-energy parts where it can be shown that there is no propagation to hazardous engine effects.

(4) Vibration levels that result in crew discomfort.

(5) Concentration of toxic products in the engine bleed air for the cabin sufficient to degrade crew performance. Note: This item may be interpreted as the generation and delivery of toxic products as a result of abnormal engine operation that would incapacitate the crew or passengers, except that the toxic products are slow-enough acting and/or are readily detectable so as to be stopped by crew action prior to incapacitation. Possible reductions in crew capabilities due to their exposure while acting in identifying and stopping the toxic products shall be considered, if appropriate. Since these concentrations are of interest to the installer, information on delivery rates and concentrations of toxic products in the engine bleed air for the cabin should be provided to the installer as part of the installation instructions.

(6) Thrust in the opposite direction to that commanded by the pilot, below the level defined as hazardous.

(7) Generation of thrust greater than maximum rated thrust.

(8) Loss of engine support loadpath integrity.

(9) Significant uncontrollable thrust oscillation.

20. **OTHER CONSIDERATIONS**.

a. Improper operation. Errors in operation of the engine have resulted in hazardous or catastrophic effects at the aircraft level which otherwise would have been less serious. Consideration should be given to mitigating the effects of improper operation or to providing operating instructions that reduce the likelihood of improper operation. In

particular, abnormal engine symptoms and their desired response or appropriate procedures for trouble shooting for these symptoms should be communicated to the installer (reference §33.5).

b. Assembly. Parts, the incorrect assembly of which could result in hazardous engine effects, should be designed so as to minimize the risk of incorrect assembly, or, if this is not practical, be permanently marked so as to indicate their correct position when assembled. Additional information on this subject may be found in JAR-E Section 110.

21. ANALYTICAL TECHNIQUES.

a. The depth and scope of an acceptable safety assessment depends on the complexity and criticality of the functions performed by the system(s), components or assemblies under consideration, the severity of related failure conditions, the uniqueness of the design and extent of relevant service experience, the number and complexity of the identified causal failure scenarios, and the detectability of contributing failures.

b. This section describes various techniques for performing a safety analysis. Other comparable techniques exist and may be proposed by an applicant. Variations and/or combinations of these techniques are also acceptable. For derivative engines, it is acceptable to limit the scope of the analysis to modified components or operating conditions and their effects on the rest of the engine. Early agreement between the applicant and the engine certification office should be reached on the scope and methods of assessment to be used.

c. Various methods for assessing the causes, severity levels, and likelihood of potential failure conditions are available to support experienced engineering judgment. The various types of analyses are based on either inductive or deductive approaches. Brief descriptions of typical methods are provided below. More detailed descriptions of analytical techniques may be found in the documents referenced in paragraph 2 of this AC, Related Reading Material.

(1) Failure Modes and Effects Analysis (FMEA). A structured, inductive, bottom-up analysis which is used to evaluate the effects on the engine system of each possible element or component failure. When properly formatted, it will aid in identifying latent failures and the possible causes of each failure mode.

(2) Fault tree or Dependence Diagram (Reliability Block Diagram) Analyses. Structured, deductive, top-down analyses which are used to identify the conditions, failures, and events that would cause each defined failure condition. These are graphical methods of identifying the logical relationship between each particular failure condition and the primary element or component failures, other events, or their combinations that can cause the failure condition. A Fault Tree Analysis is failure oriented, and is conducted from the perspective of which failures must occur to cause a defined failure condition. A Dependence Diagram Analysis is success-oriented, and is conducted from the perspective of which failures must not occur to preclude a defined failure condition.

FAA Action – Not Available